US-PAT-NO: 5786979

DOCUMENT-IDENTIFIER: US 5786979 A

TITLE: High density inter-chip connections by electromagnetic coupling

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Detailed Description Text - DETX (31):

While the invention has been described with respect to the embodiments and variations set forth above, these embodiments and variations are illustrative and the invention is not to be considered limited in scope to these embodiments and variations. For example, the materials, dimensions, and geometric configurations may be varied. Furthermore, chips may use electro-magnetic coupling devices in conjunction with conventional interconnection techniques. For example, capacitor plate layers may overlie only selected portions of a chip which allows for conventional wire connections to remaining portions of the chip. Additionally, although capacitive coupling has been described, inductive coupling or a combination of inductive and capacitive coupling may be used to provide inter-chip communication of time-varying signals. Accordingly, various other embodiments and modifications and improvements not described herein may be within the spirit and scope of the present invention, as defined by the following claims.

# Application Note # 5434a

## Electrical Noise in Motion Control Circuits

### *1. Origins of Electrical Noise*

Electrical noise appears in an electrical circuit through one of four routes:

a. Impedance (Ground Loop) Coupling
b. Capacitive (Electrostatic) Coupling
c. Inductive (Magnetic) Coupling
d. Electromagnetic (Radio Frequency) Coupling

**Impedance (Ground Loop) Coupling**
Impedance coupling, sometimes referred to as ground loop, is very common in servo systems. Systems at risk include those with sensors and devices connected at various physical locations on a machine at distances of one foot and greater. The impedance of a wire or device is a combination of the resistance, capacitance, and inductance properties. In theory, wire connections in a circuit are assumed to have zero impedance but in practice this is not the case. The voltage level of a ground wire varies at different locations on the wire, and if this voltage difference is high enough than unpredictable performance can result. For example, consider this simple circuit:

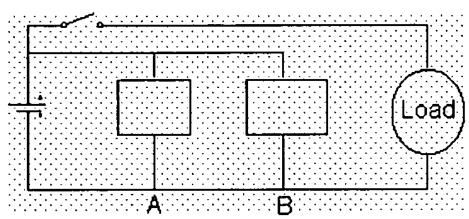



Fig. 1- Simple Circuit (1)

The wire used to connect the ground points in the circuit is ordinary AWG No 12 wire, which has a resistance rating of 1.6W for every 1000 feet of wire. For this circuit, the distance between points A and B is 50 feet. The resistance of the piece of wire is then calculated:

$$R_{AB} = \frac{50}{1000} \bullet 1.6 = 0.08\Omega \qquad \text{Eq. (1)}$$

If the load in circuit (1) is a solenoid that draws 0.5 A from the power supply Vs, the voltage drop between points A and B is non zero:

$$V_{AB} = 0.5 \cdot 0.08 = 0.04V \qquad \text{Eq. (2)}$$

The signal at the controller input will then appear to have changed by 0.04V. TTL specifications are that logic 0 is between 0 and 0.7 volts, so the 0.04V will not have an impact.

However, when the 0.5A current through the solenoid is interrupted by the switch, the current can drop from 0.5A to 0 in less than 1 ms. This rapid change in current in the ground line can induce a voltage due to the self-inductance of the wire. Normally an inductance is associated with a coil, but a straight wire will also have an associated inductance. The formula for the self-inductance of a straight wire at high frequency is given by:

$$L = 0.002l\left[\log_e \frac{2l}{r} - \frac{3}{4}\right] \mu H \qquad \text{Eq. (3)}$$

Where *l* is the length of the wire in centimeters and *r* is the radius of the conductor in centimeters. For wire AB, the inductance is calculated to be 27 mH. When the current through the load is interrupted, the current changes from 0.5A to 0 in 1 ms, and the voltage between points A and B is:

$$\begin{aligned} V_{AB} &= L\frac{di}{dt} \\ V_{AB} &= 27 \cdot 10^{-6} \cdot \frac{0.5}{10^{-6}} \\ V_{AB} &= 13.5V \end{aligned} \qquad \text{Eq. (4)}$$

The voltage calculated is a peak voltage, but in a digital circuit the reaction of the circuit occurs within nanoseconds.

Impedance of a signal wire can be shown to cause similar problems. Some amplifiers are sensitive to certain values of input impedance. This is seen in the cable length limitations for a device, where the cable length limit is due to known impedance limitations of the output amplifier.

**Capacitive (Electrostatic) Coupling**

Capacitance is defined as a voltage charge on one device causing a resultant voltage rise on another device in close proximity. Capacitive coupling in a digital circuit occurs when a voltage on one signal wire creates a voltage on another signal wire. Capacitive coupling is also called "crosstalk", a term originating from telephone wiring technicians. Capacitive coupling is a problem since the state of a digital circuit is based on voltage levels of only a few volts. A variation of 2 volts means the difference between logic 0 and logic 1.

A common source of relatively high voltage is a coil in a high power relay or solenoid. When the current to the relay coil or solenoid is rapidly severed the collapsing magnetic field causes a large voltage spike. For example, a 12V relay with a 100mA current in the coil can create a voltage spike as large as 500 V when the coil current is disconnected. This voltage spike in the load circuit on the left in the diagram below will create a voltage in the signal wires of the motion control system circuit on the right.

Controller Output Signals

Fig. 2- Capacitive Noise Circuit

**Inductive (Magnetic) Coupling**

Magnetic coupling occurs when a current in one wire creates a current in another wire. A common example can be found in a transformer. Inductive coupling is usually due to low frequency magnetic fields, such as a 50 or 60 Hz power transformer. Such a device could be used to supply DC power to a servo amplifier or stepper motor drive. The power wires for the motor are also a source of magnetic fields because of the high currents involved, and the relatively low PWM frequency in the tens of kilohertz.

**Electromagnetic (Radio Frequency) Coupling**

The noise voltages caused by magnetic or capacitive coupling are referred to as near field effects because the noise source is in close proximity to the controller signal circuits. When longer distances are involved, the noise coupling is due to a field propagating as radio frequency waves or electromagnetic radiation. Radio wave noise, sometimes referred to as RF noise, is defined as noise transmitted through distances greater than 1/6 of the wavelength of the noise. Here are some example distances for different signal frequencies:

| Frequency | 1/6 Wavelength |
|---|---|
| 1 MHz | 1970 in (5000 cm) |
| 10 MHz | 197 in (500 cm) |
| 100 MHz | 19.7 in (50 cm) |
| 1 GHz | 1.97 in (5 cm) |

Radio frequency interference (RFI) on specific frequencies is commonly caused by the use of wireless equipment such as local use of walkie-talkies or cellular phones. However, if there is a plasma torch in the vicinity or some other type of very high power arcing device such as welding equipment, the RF noise is spread across the whole spectrum and can certainly cause problems in a motion control system.

## *2. Noise Reduction Techniques*

### Ground loop Elimination

It is essential to eliminate ground loops in a digital servo system. Figure 3 shows a poorly wired ground circuit.

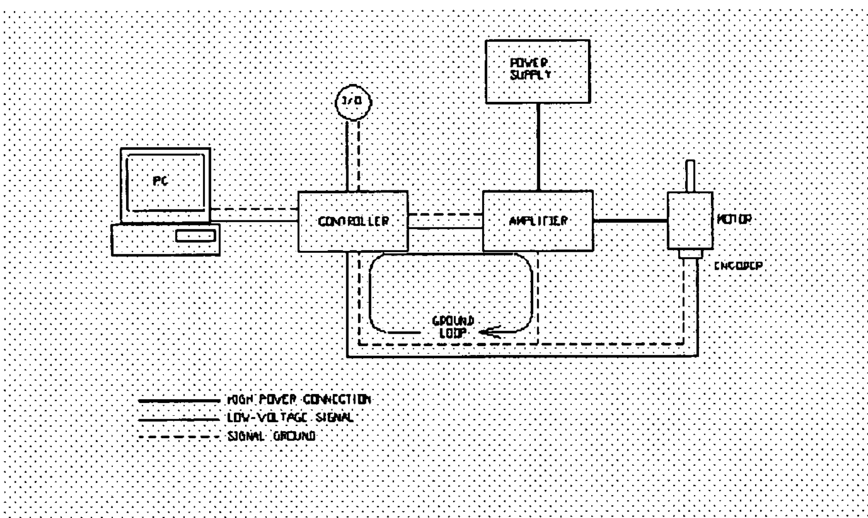
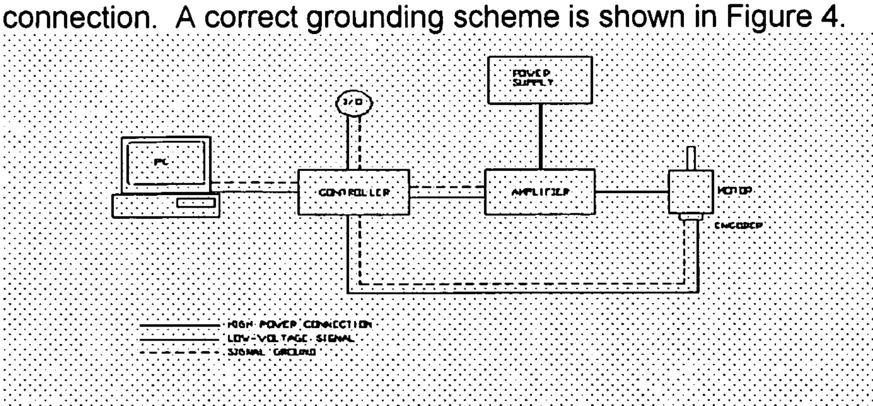



Fig 3. A poorly wired ground circuit

To test for ground loops, check for signal ground continuity between components. Remove the one desired ground connection, and re-test for continuity. If a low-impedance path still exists, remove any ground connections until the path is eliminated. Then reconnect the essential ground connection. A correct grounding scheme is shown in Figure 4.



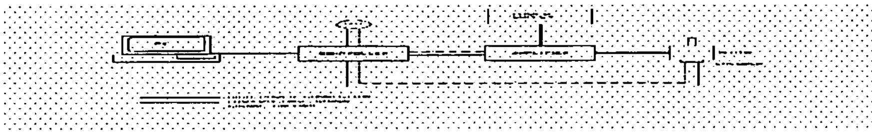


Fig. 4- Desirable ground circuit

**Capacitive Noise Reduction**

The challenge facing the user is to reduce the induced voltages without changing the function of the high-powered circuit. Several options exist:

1. Reduce The Source Voltage

Since the noise on the signal line is proportional to the voltage on the wires of the noise source, for example a relay coil, then reducing the voltage on the noise source wires means less noise on the signal wires. If the noise source is a relay or solenoid changing states, a diode connected in parallel with the coil will bypass the voltage spike back into the coil and reduce the voltage. Here is an example circuit:

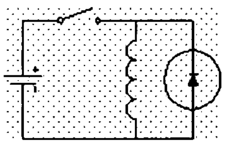


Fig. 5- Voltage spike reduction across a solenoid

2. Reduce Wire Proximity

The noise in the control system circuit is proportional to the amount of capacitance between the noise circuit and the control system circuit, so if the capacitance is reduced, the noise is reduced. Sub-optimal distances are shown in Figure 6.

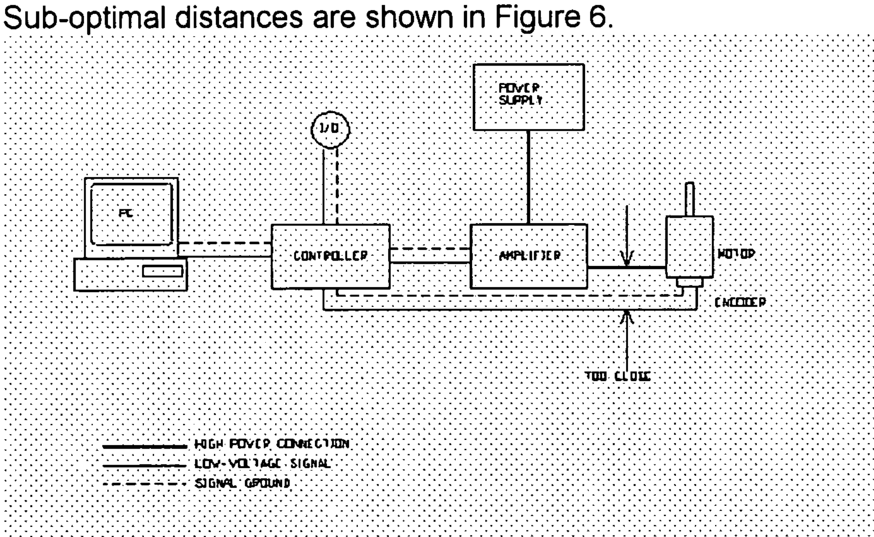
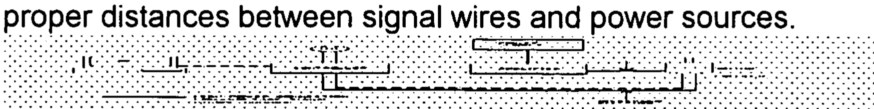



Fig. 6- Signal wires too close to power leads

Capacitance between two conductors is inversely proportional to the square of the distance between the conductors. By doubling the distance between the noise circuit and the control system circuit the capacitance will be ¼ of its previous value. Figure 7 illustrates a circuit utilizing proper distances between signal wires and power sources.



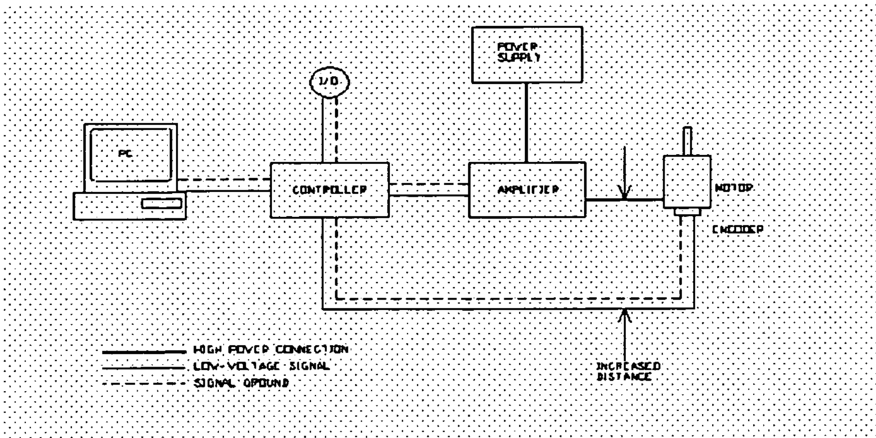


Fig. 7- Proper distancing of signal cables

3. Shielding
Wire shielding is the best method for reducing capacitive noise on a signal wire. Shield connections should drain to Earth ground, and should not be connected to the signal ground of the circuit. Shields should only be connected at one end. Figure 8 shows proper shield connections.

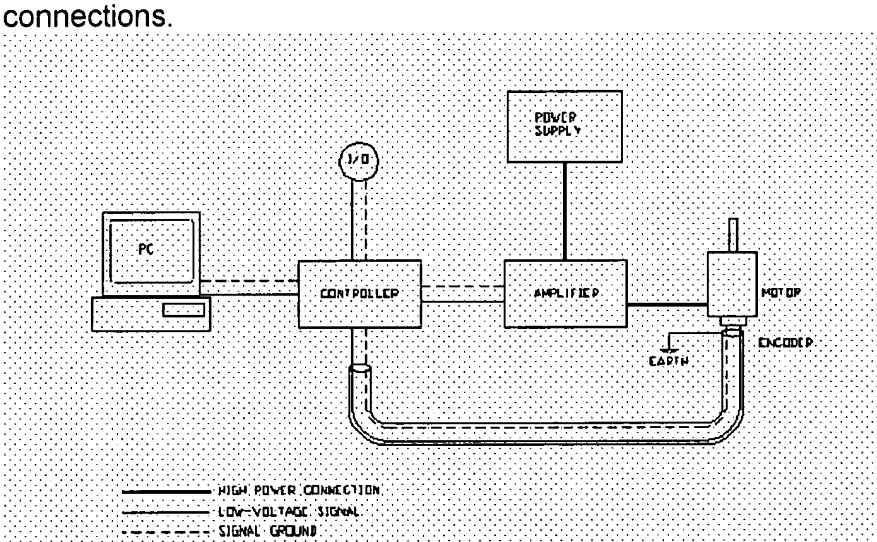


Fig. 8- Proper shield wiring

4. Reduce Wire Lengths
Capacitive coupling is a serious problem when using ribbon cables, because of the close proximity of one signal wire to another. The Econo and Legacy series controllers carry the signals of up to 4 encoders on one 37 pin and one 60-pin ribbon cable. Shielding is not a viable solution in this case. Shortening the length of the ribbon cable as much as possible reduces the effect, as does using ribbon cable that has individual twisted pairs of wires. When connecting the encoders to the breakout board, separate the encoder signals for each axis by using separate shielded cables for each encoder. If encoders with differential line driver outputs are used, then the distance for each individual encoder shielded cable can be 10, 20, 30 feet and up. Newer products, such as the Optima series, use a shielded SCSI-type cable. While this style of cable provides considerable noise immunity, ensure that the shortest possible cable is specified.

**Magnetic Coupling Noise reduction**

Since this noise coupling is due to current, and the current that produces the noise is necessary

for some device such as the motor to operate, reducing the current is not a workable solution. Also, low frequency magnetic fields are not significantly reduced by metal enclosures or shielding.

Increasing the distance between the power wires and the signal wires is the best method of reducing this type of problem. Inductance between two circuits is inversely proportional to the square of the distance between the circuits, so doubling the distance between the wires reduces the inductance by a factor of four.

Twisting of the power wires can also reduce the inductance between the circuits and is highly recommended. For example, a DC brush servo motor has two power wires connecting the motor to the servo amplifier. Figure 9 shows standard, untwisted power leads.

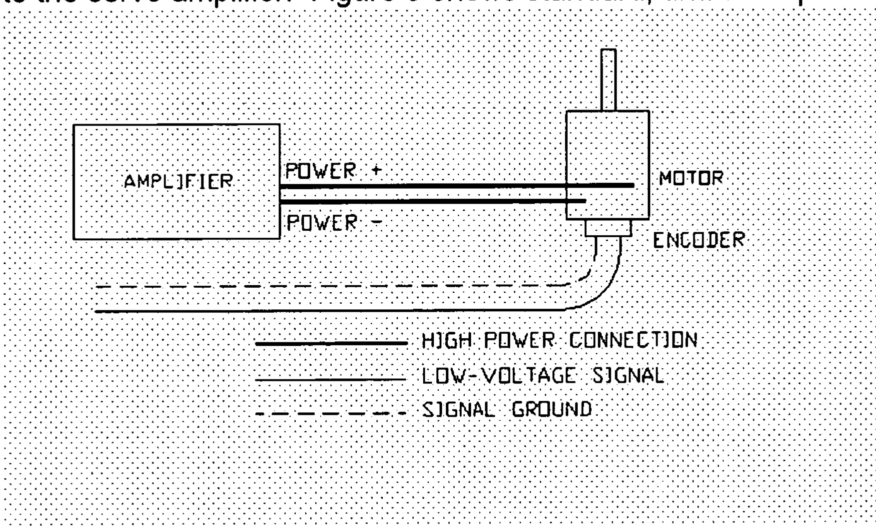



Fig. 9- Power leads untwisted

Intuitively, the servo motor wires and encoder wires will run side by side back to the servo amplifier and motion controller. The wires are close to each other and will have an inductive path between them, but twisting the motor power wires reduces the enclosed area between the two circuits and therefore reduces the inductance significantly. Figure 10 shows twisted power leads.

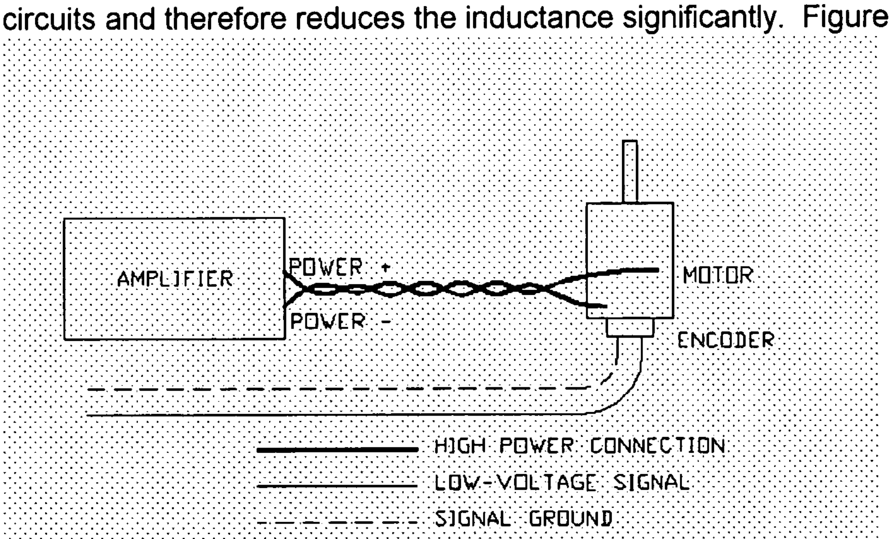



Fig. 10- Twisted power leads

**Radio Frequency noise reduction**

1. Shield
Protective shielding is vital to avoid RF pickup, and this shield must surround the entire motion control circuit with a conductive path, and the shield must then connect to earth ground. At no point should you connect shield to one of the ground points of the motion controller, as this will introduce the noise directly into the controller circuitry. Figure 11 shows proper control system isolation.

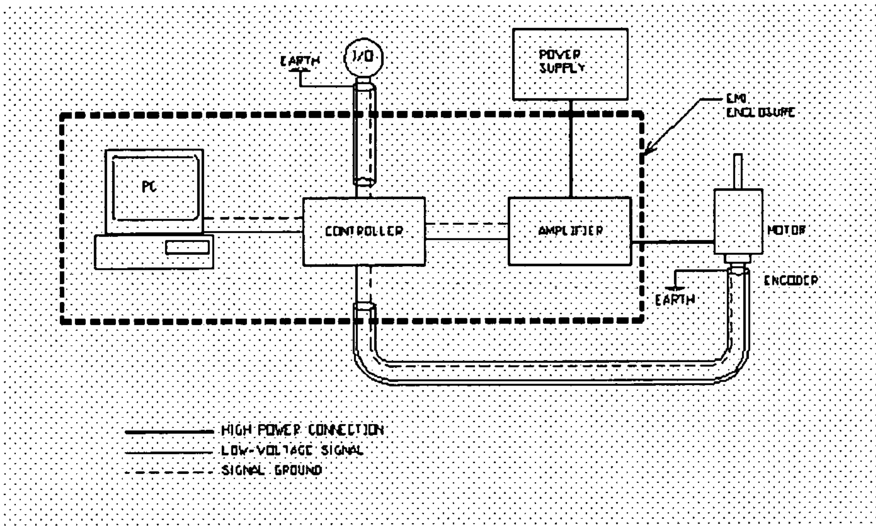



Fig. 11- Example EMI enclosure

2. Ground
You must avoid connecting the signal ground of the controller through a wire to earth ground. Connecting additional wires from the controller ground to earth ground will act as an antenna, and RF noise will appear as ground line voltages and disturb controller operation.

3. Keep Wires Short
As with other noise coupling types, long signal lines are more prone to receiving RF noise. Keep all signal wires as short as possible.

## *3. Design Considerations*

Unfortunately, in many cases the only test of a circuit's susceptibility to noise is to place the control system into operation. Since industrial environments vary a great deal, it is impossible to completely predict noise problems. If you see any of these symptoms, then noise is a possible cause:

1. Noise On Encoder Wires
If your position moves stop short or move too far, although the controller reports no position error, this suggests noise on the encoder signal lines. This noise can be a ground loop problem obscuring the encoder pulses, or enough noise on the encoder lines that they are counted as if they were real encoder pulses. Using an encoder that has differential, line driver outputs (A+, A-, B+, B-) are much more noise resistant. Termination of differential signals further improves the noise immunity. The terminating resistor value is a function of the device's output circuit drive capacity. Quadrature encoding is also much more noise immune than simple pulse and direction. If you do use a single ended output, make sure to leave the A- and B- open. Connecting these inputs to ground will disable the encoder inputs.

2. Servo Motor Oscillation

This is usually a problem during initial setup, and encoder noise again can cause this. One other common cause is a bad wiring connection. Many servo amplifiers will have a differential input, for example the Galil MSA-12-80 has a Vref+ and Vref- input as well as signal ground. The Galil controllers all have single ended outputs, however, and it is intuitive to connect the unused Vref- input to ground. However, the Vref- input is already pulled to ground through a resistor on the MSA-12-80 input circuit. Impedance coupling on the ground wire is amplified by this connection, as a small ground current now becomes a voltage on the servo amplifiers input.

3. Controller sporadically resets, loses communication, or crashes to monitor prompt (>)
This is a very serious problem, and occurs for a very simple technical reason. All Galil controllers have circuitry on board that monitors the +5V supply voltage. When this voltage drops below 4.75 V, the circuitry resets the on-board processor. Two items can potentially cause this. Ground loops, as discussed before, can be the cause. Another potential source is the power supply itself; many modern, inexpensive switching power supplies can contain high frequency (100kHz) noise on any or all of the supply voltages. Use an oscilloscope to determine if the power supply is causing such disturbances.
In Pentium-based computers rated at greater than 133 MHz, a special active mode is enabled during high-intensity graphical operations, such as screen refresh and rapid mouse moves. When switching into and out of this mode, the CPU can produce a voltage surge or drop on the 5 volt supply line. A high-quality power supply can absorb these voltage spikes.

Here are some rule of thumb to follow that help avoid noise problems in a motion control system design:

- Avoid long ground wire paths and especially avoid large loops of ground wiring
- Twist pairs of power wires from DC power supplies, DC brush motors to avoid inductive coupling
- Keep low-level signal wires as far away as possible from high power wires
- Do not connect motion controller's A- or B- encoder inputs to ground with single-ended controllers
- Do not connect servo or stepper motor drive negative inputs to ground
- Use diode snubber across relay and solenoid coils to reduce inductive kick back voltage
- Place filter chokes around signal wires and/or ribbon cables to filter high frequency noise
- Use the shortest ribbon cabling possible, or use twisted pair ribbon cables
- Don't connect shield wires to the controller ground, and don't connect controller ground to earth
- If the AC power line is shown to be noisy, install an isolation transformer on the incoming line or a Uninterruptable Power Supply (UPS) with a line conditioner/filter.
- Check 5V line for spikes (surges) on PC-power supplies for bus-based controllers that reset or lose communication.

Although the suggestions related in this discussion are proven techniques for reducing system noise, occasionally a system will continue to function poorly. If any further assistance is required, feel free to contact Technical Support at Galil Motion Control at 1.800.377.6329 or at support@galilmc.com.

Jan. 14, 1936. R. I. KINROSS 2,027,986

SUPERHETERODYNE RECEIVER

Filed Nov. 10, 1933

Fig. 1

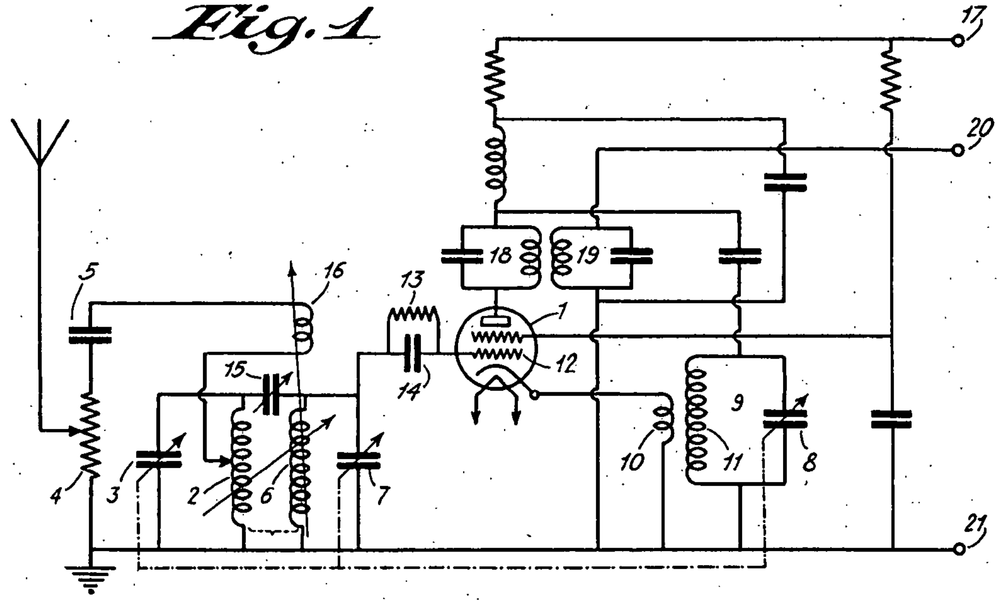



Fig. 2

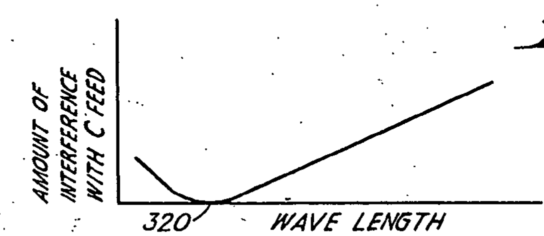



Fig. 3

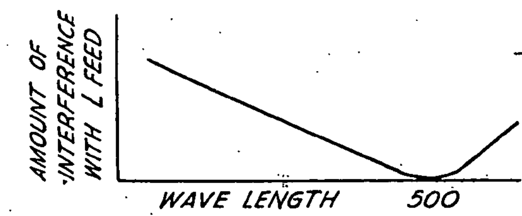
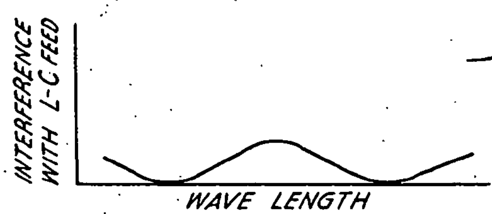



Fig. 4

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RUPERT I. KINROSS
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ATTORNEY

US005578981A

# United States Patent [19]

**Tokuda**

[11] **Patent Number: 5,578,981**

[45] **Date of Patent: Nov. 26, 1996**

[54] **LAMINATED INDUCTOR**


[75] Inventor: **Hiromichi Tokuda**, Nagaokakyo, Japan

[73] Assignee: **Murata Manufacturing Co., Ltd.**, Nagaokakyo, Japan



[21] Appl. No.: **57,670**

[22] Filed: **May 5, 1993**

[30] **Foreign Application Priority Data**

May 8, 1992 [JP] Japan .............................. 4-030021 U

[51] **Int. Cl.**[6] .................................................. **H01G 27/30**

[52] **U.S. Cl.** ........................ **336/171**; 333/185; 336/200; 336/223

[58] **Field of Search** .................................... 336/200, 232, 336/233, 234, 170, 171, 192, 223, 225; 333/185


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*Primary Examiner*—Thomas J. Kozma
*Attorney, Agent, or Firm*—Burns, Doane, Swecker & Mathis, LLP

[57] **ABSTRACT**


A laminated inductor which is adopted in an electronic circuit. The laminated inductor has a plurality of coil sections which are composed by laminating insulating layers and coil conductors alternately. The two adjacent coil sections are staggered at least either in the vertical direction or in the horizontal direction.


**3 Claims, 7 Drawing Sheets**

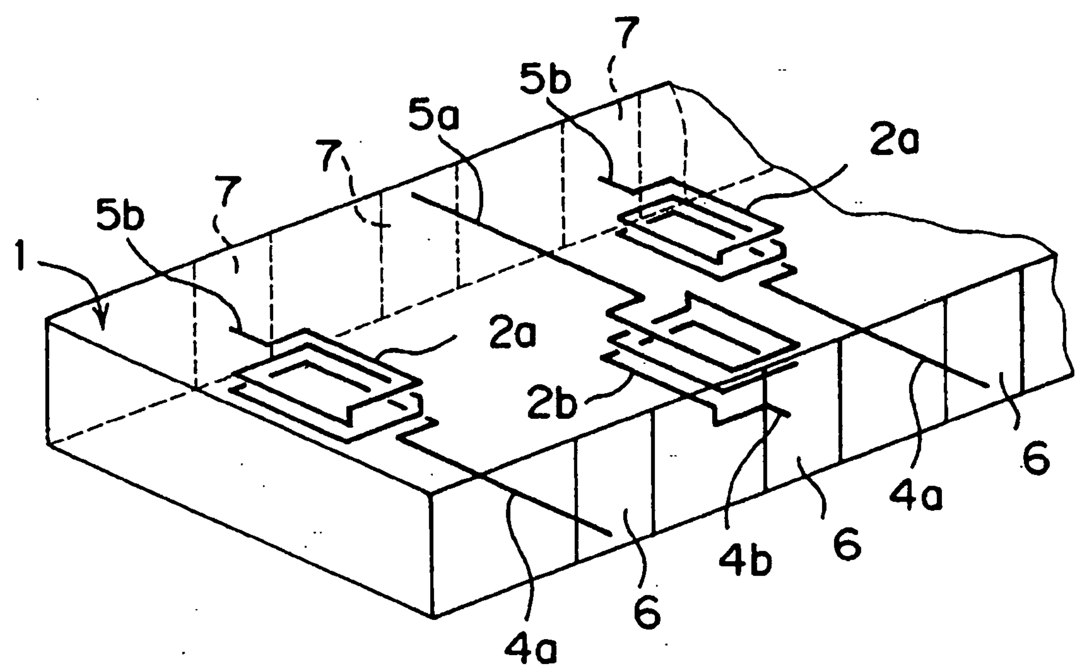

FIG. 1

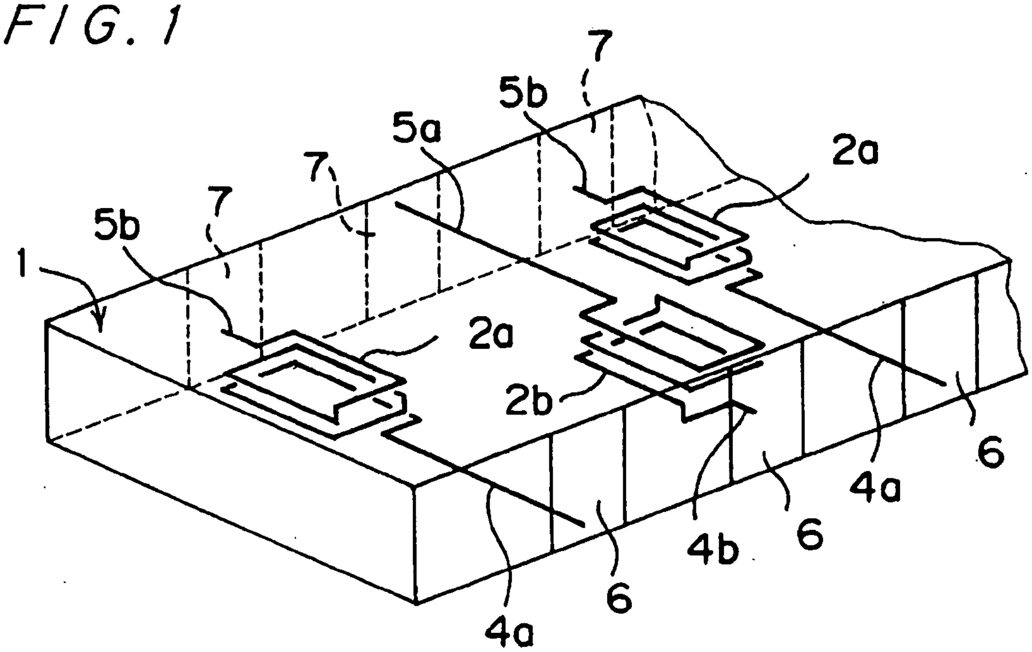

FIG. 2

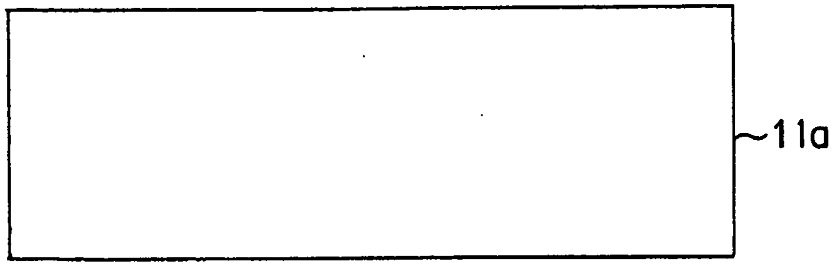


FIG. 3

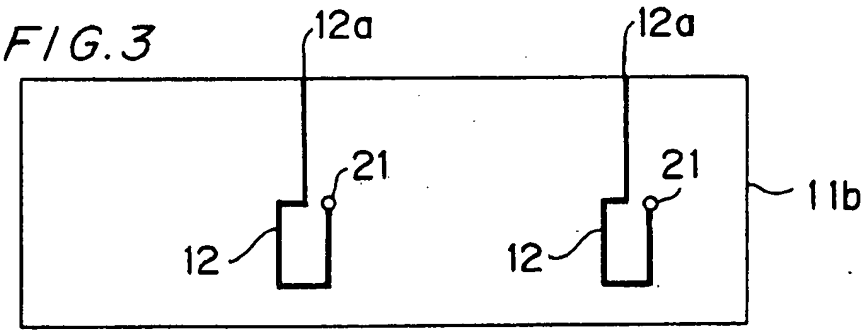


FIG. 4

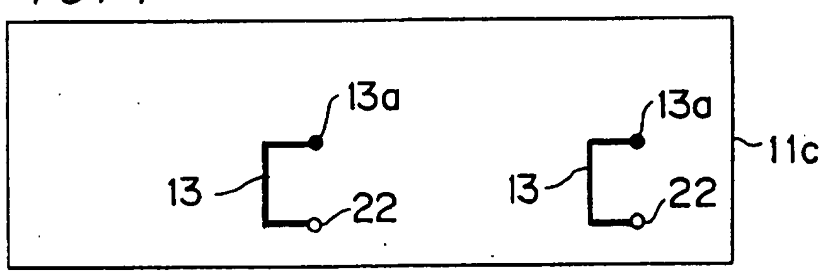


FIG. 5

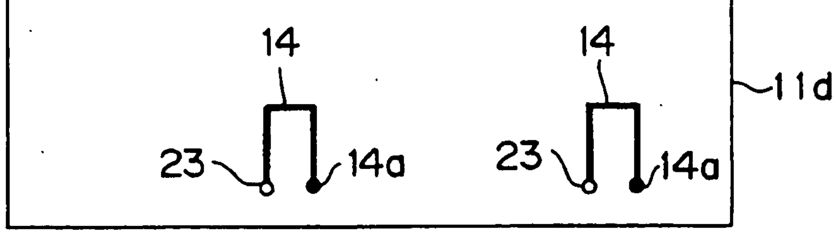

FIG. 6

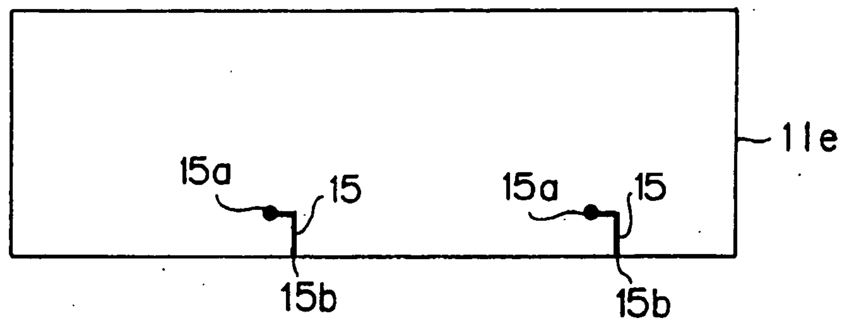


FIG. 7

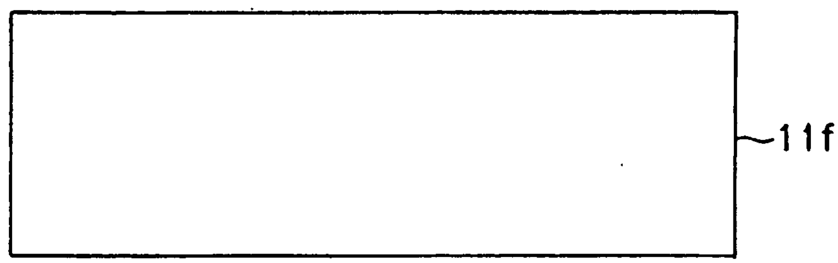


FIG. 8

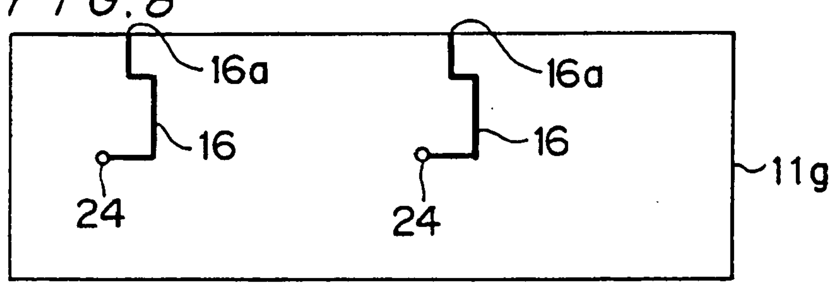


FIG. 9

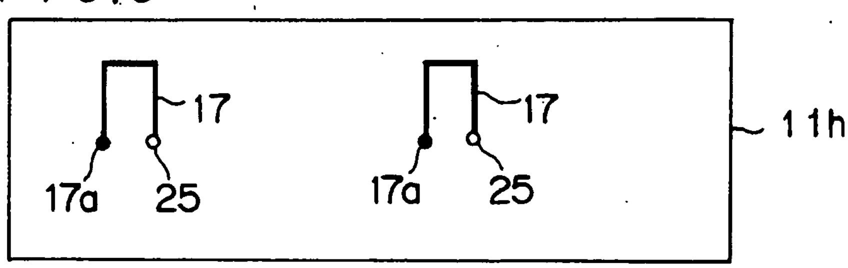

FIG. 10

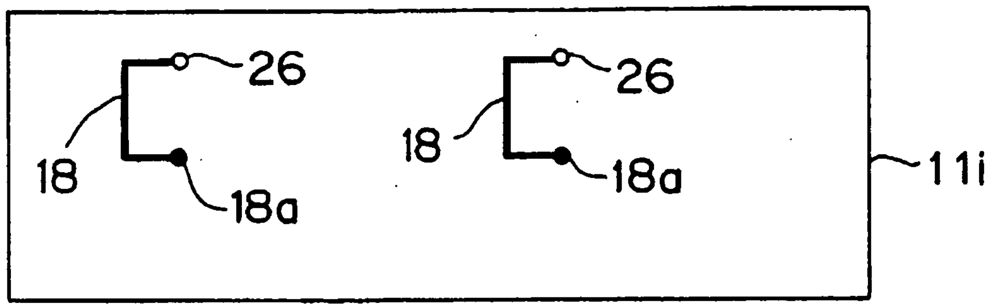


FIG. 11

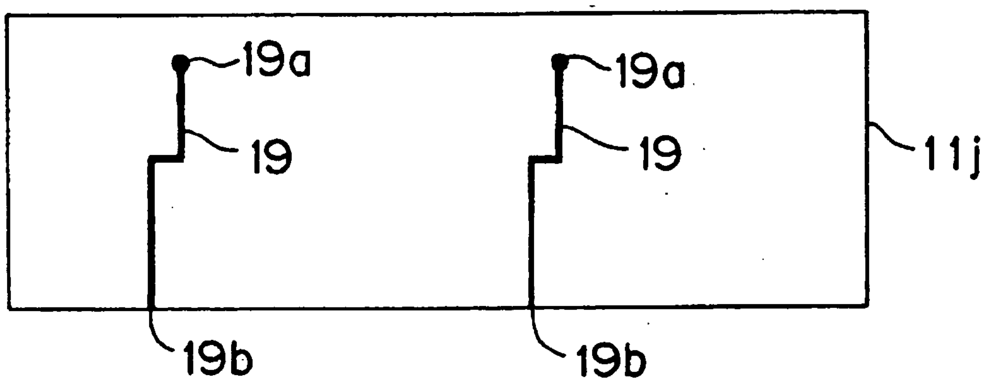


FIG. 12

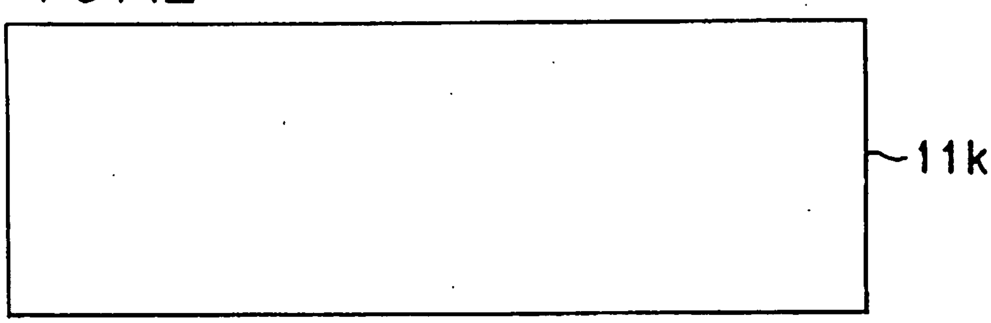

FIG. 13

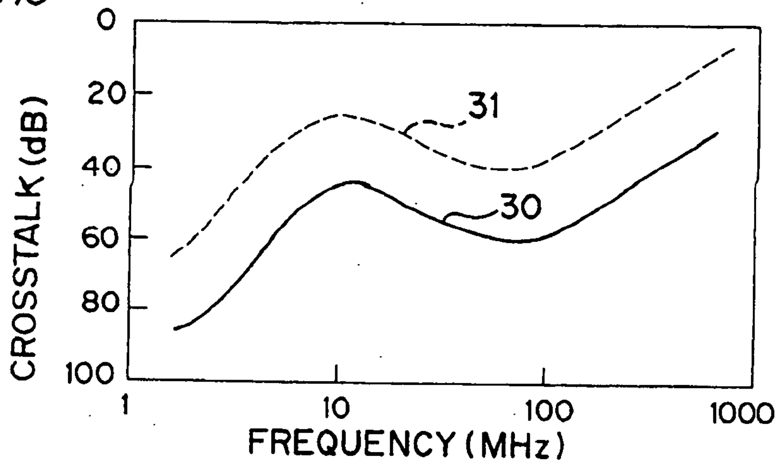


FIG. 14

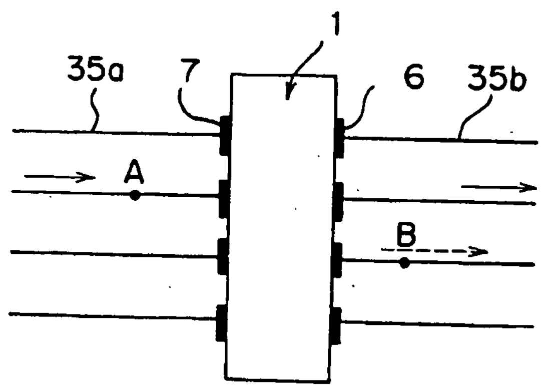


FIG. 15

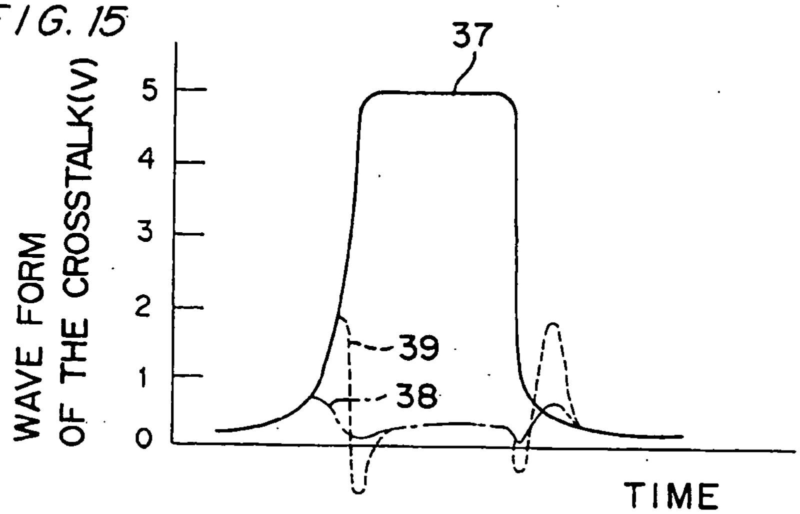

FIG. 16

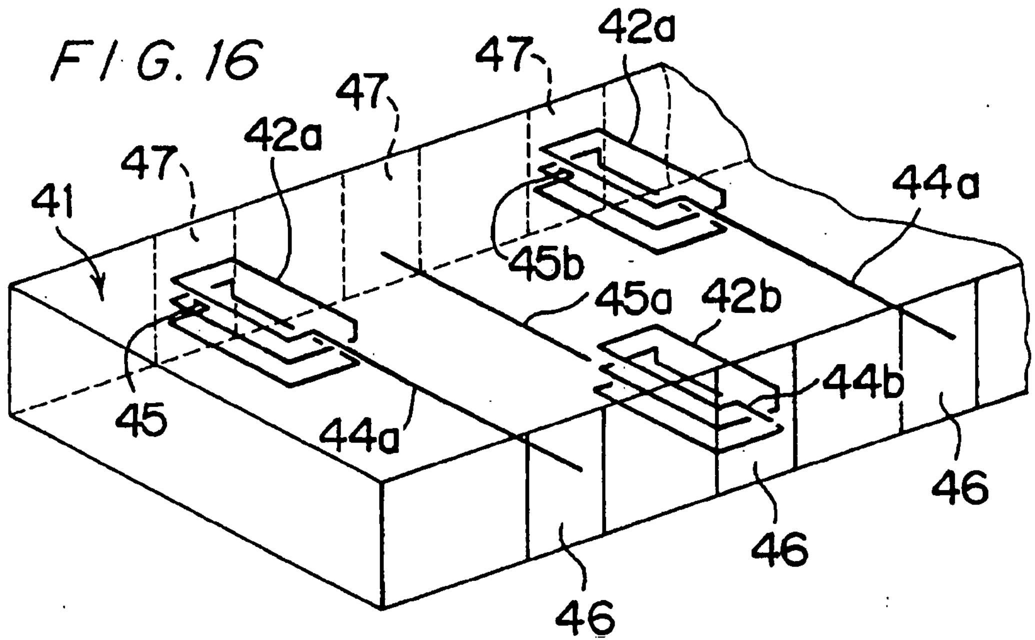
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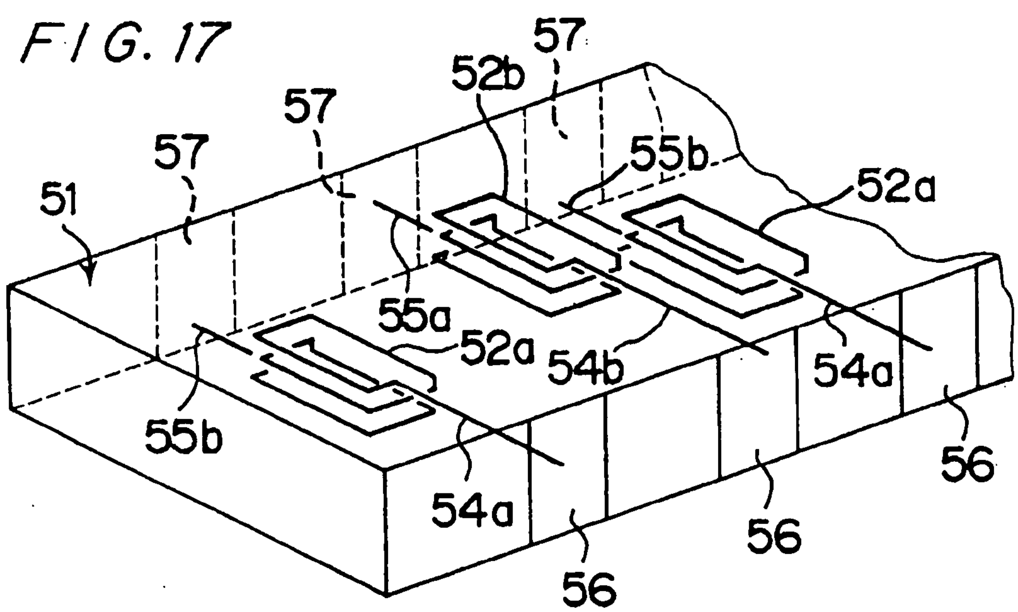
FIG. 17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56
56
56

FIG. 18

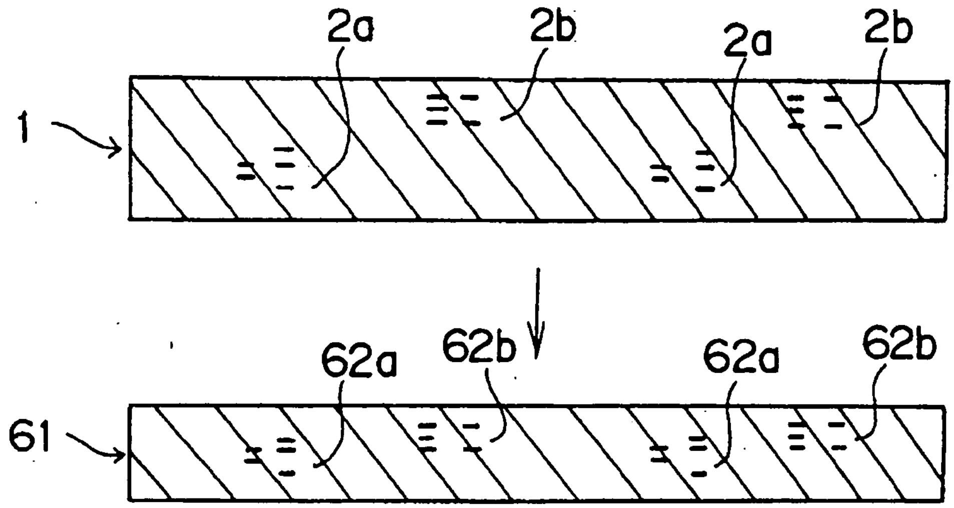
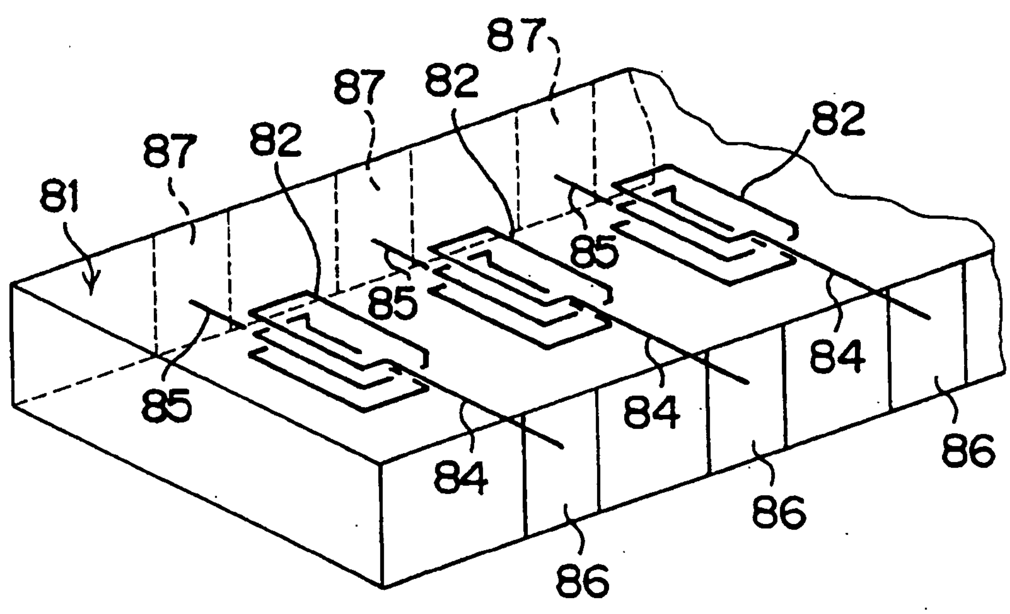



FIG. 19 PRIOR ART



# LAMINATED INDUCTOR

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a laminated inductor which is installed in an electronic circuit.

2. Description of Related Art

Conventionally, a laminated inductor **81** shown in FIG. **9** has been used for avoiding electromagnetic interference and maintaining immunity of IC parts. The inductor **81** comprises a plurality of coil sections **82** which are composed by laminating insulating layers and coil conductors alternately. Both ends of each coil section **82** are connected with external electrodes **86** and **87** through leading sections **84** and **85**.

However, up to now, since all the coil sections **82** are provided at the same level in a vertical direction and provided in a line in a horizontal direction, spaces between the adjacent coil sections **82** are narrow and a large crosstalk is caused between the coil sections **82** by inductive coupling and capacitive coupling. Particularly, when a pitch between the external electrodes **86** and **87** becomes narrow by downsizing of the inductor **81**, the spaces between the coil sections **82** become narrower and the crosstalk becomes larger. This may cause a wrong operation of the IC parts to be protected.

## SUMMARY OF THE INVENTION

An object of the present invention is to provide a laminated inductor which has a structure to decrease a cross-talk between adjacent coil sections.

In order to attain the object, a laminated inductor according to the present invention comprises a plurality of coil sections which are composed by laminating insulating layers and coil conductors alternatively, the two adjacent coil sections being staggered at least either in a vertical direction or a horizontal direction of the inductor.

In the above structure, since the two adjacent coil sections are staggered at least either in the vertical direction of the inductor or in the horizontal direction, the space between adjacent coils become larger. Thus, the crosstalk which is caused by inductive coupling and capacitive coupling between the coil sections becomes smaller.

Further, by staggering leading sections which are connected with the two adjacent coil sections in the vertical direction, the crosstalk which is caused by the conductive coupling and the capacitive coupling between the coil sections and the leading sections can be decreased.

## BRIEF DESCRIPTION OF THE DRAWINGS

This and other objects and features of the present invention will become apparent from the following description taken in conjunction with the preferred embodiments in reference to the accompanying drawings, in which:

FIG. **1** is a perspective view which shows a structure of a first embodiment of a laminated inductor according to the present invention;

FIGS. **2** through **12** are plan views which show insulating sheets used in the laminated inductor shown in FIG. **1**;

FIG. **13** is a graph which shows a measuring result of a crosstalk of the laminated inductor shown in FIG. **1**;



FIG. **14** is an electric circuit diagram of the laminated inductor shown in FIG. **1** in a condition of being connected with signal transmitting lines;

FIG. **15** is a graph which shows wave forms of the crosstalk of the electric circuit shown in FIG. **14**;

FIG. **16** is a perspective view which shows a structure of a second embodiment of the laminated inductor according to the present invention;

FIG. **17** is a perspective view which shows a structure of a third embodiment of the laminated inductor according to the present invention;

FIG. **18** is a sectional view which shows a modifications of the laminated inductor shown in FIG. **1**; and

FIG. **19** is a perspective view which shows a structure of a conventional laminated inductor.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The description of preferred embodiments according to the present invention is given below, referring to the drawings.

### FIRST EMBODIMENT: FIGS. 1 THROUGH 15

As shown in FIG. **1**, a laminated inductor **1** comprises a plurality of coil sections **2*a*** and **2*b*** which are composed or formed by laminating insulating layers and coil conductors alternately. More specifically, the coil sections **2*a*** and **2*b*** are formed by connecting coil conductors electrically through through holes which are provided on the insulating layers. The coil sections **2*a*** and **2*b*** are staggered in the vertical direction and the horizontal direction of the inductor **1**. Therefore, the space between two adjacent coil sections **2*a*** and **2*b*** is larger than the space between two adjacent coil sections of the conventional inductor.

Both ends of the coil sections **2*a*** and **2*b*** are connected with inline type external electrodes **6** and **7** which are provided on sides of the inductor **1** through leading sections **4*a***, **4*b***, **5*a*** and **5*b***. The leading section **4*a*** is provided at a lower part of the inductor **1**, whereas and the adjacent coil section **2*b*** is provided at an upper part of the inductor **1**. In the same way, the leading section **5*a*** is provided at the upper part of the inductor **1**, and the adjacent coil section **2*a*** is provided at the lower part of the inductor **1**. Thereby, crosstalks between the coil section **2*a*** and the leading section **5*a*** and between the coil section **2*b*** and the leading section **4*a*** are decreased.

A manufacturing process of the laminated inductor is explained below referring to FIG. **2** through FIG. **12**. Conductors **12**, **13**, **14**, **15**, **16**, **17**, **18** and **19** for forming a coil are provided on insulating sheets **11*b***, **11*c***, **11*d***, **11*e***, **11*g***, **11*h***, **11*i*** and **11*j*** respectively. Insulating sheets **11*a*** and **11*k*** are used as protective layers. An insulating sheet **11*f*** is used as an intermediate layer. These insulating sheets **11*a*** through **11*k*** are laminated to form the inductor **1**. As a material of the insulating sheets **11*a*** through **11*k***, for example, ferrite can be used.

As shown in FIG. **2**, nothing is provided on the insulating sheet **11*a***. As shown in FIG. **3**, ends **12*a*** of two coil conductors **12** which are provided on the insulating sheet **11*b*** are exposed at a side of the insulating sheet **11*b***. Through holes **21** are provided at the other ends of the coil conductors **12**. As shown in FIG. **4**, two coil conductors **13** are provided on the insulating sheet **11*c***. Pads **13*a*** are provided at ends of the coil conductors **13**. Through holes **22**

are provided at the other ends of the coil conductors 13. As shown in FIG. 5, two coil conductors 14 are provided on the insulating sheet 11*d*. Pads 14*a* are provided at ends of the coil conductors 14, and through holes 23 are provided at the other ends of the coil conductors 14. As shown in FIG. 6, two coil conductors 15 are provided on the insulating sheet 11*e*. Pads 15*a* are provided at ends of the coil conductors 15. The other ends 15*b* of the coil inductors 15 are exposed at a side of the insulating sheet 11*e*. As shown in FIG. 7, nothing is provided on the insulating sheet 11*f*. As shown in FIG. 8, two coil conductors 16 are provided on the insulating sheet 11*g*. Ends 16*a* of the coil conductors 16 are exposed at a side of the insulating sheet 11*g*. Through holes 24 are provided at the other ends of the coil conductors 16. As shown in FIG. 9, two coil conductors 17 are provided on the insulating sheet 11*h*. Pads 17*a* are provided at ends of the coil conductors 17, and through holes 25 are provided at the other ends of the coil conductors 17. As shown in FIG. 10, two coil conductors 18 are provided on the insulating sheet 11*i*. Pads 18*a* are provided at ends of the coil conductors 18, and through holes 26 are provided at the other ends of the coil conductor 18. As shown in FIG. 11, two coil conductors 19 are provided on the insulating sheet 11*j*. Pads 19*a* are provided at ends of the coil inductors 19, and the other ends 19*b* are exposed a side of the insulating sheet 11*j*. As shown in FIG. 12, nothing is provided on the insulating sheet 11*k*.

The insulating sheets 11*a* through 11*k* are laminated in order with the insulating sheet 11*k* at the bottom and the insulating sheet 11*a* at the top. Then, the laminate of the insulating sheets 11*a* through 11*k* is sintered. The external electrodes 6 and 7 are formed on sides of the laminated inductor 1, and thereby, the laminated inductor 1 shown in FIG. 1 is made. In the laminate of the insulating sheets 11*a* through 11*k*, the coil conductors 12 through 15 are connected in series electrically by respective electrical connections between the through holes 21, 22 and 23 and the pads 13*a*, 14*a* and 15*a*, and thereby the coil section 2*b* is formed. In the same way, the coil conductors 16 through 19 are connected in series electrically by respective electrical connections between the through holes 24, 25 and 26 and the pads 17*a*, 18*a* and 19*a*, and thereby the coil section 2*a* is formed. The coil sections 2*a* and 2*b* are arranged at equal intervals. Also, the ends 12*a* of the coil conductors 12 are connected with the external electrodes 7, and thereby a part of the coil conductors 12 forms the leading section 5*a*. In the same way, the ends 15*b* of the coil conductors 15 are connected with the external electrodes 6, and thereby a part of the coil conductors 15 forms the leading section 4*b*. The ends 16*a* of the coil conductors 16 are connected with the external electrodes 7, and thereby a part of the coil conductors 16 forms the leading section 5*b*. The ends 19*b* of the coil conductors 19 are connected with the external electrodes 6, and thereby a part of the coil conductors 19 forms the leading section 4*a*.

FIG. 13 shows a measuring result of a crosstalk between two adjacent coil sections 2*a* and 2*b* provided in the above laminated inductor 1. In the laminated inductor 1 used in the measurement, the pitch among the external electrodes 6 or the external electrodes 7 is 1.27 mm, the width of the conductors of the coil sections 2*a* and 2*b* is 0.2 mm, and the resistance between a pair of external electrodes 6 and 7 is 50 Ω. The ordinate of the graph shows the crosstalk, and the abscissa shows the frequency. A solid line 30 shows the crosstalk characteristics of the laminated inductor 1 which is the first embodiment of the present invention. A dotted line 31 shows the crosstalk characteristics of a conventional laminated inductor. As is apparent from FIG. 13, the crosstalk of the laminated inductor 1 is smaller than that of the conventional laminated inductor.

Next, as shown in FIG. 14, the laminated inductor 1 is inserted between signal transmitting lines 35*a* and 35*b* to measure the wave form of the crosstalk. FIG. 15 shows the measuring result. In FIG. 15, a solid line 37 shows a wave form of an input signal at the point A shown in FIG. 14. A dashed line 38 shows a wave form of an output crosstalk at the point B shown in FIG. 14. The input signal which passes through the point A is inputted to the external electrode 7, then the signal is outputted from the external electrode 6 through the coil section 2*a*. In this case, when the signal goes through the coil section 2*a*, the crosstalk is caused between the coil section 2*a* and its adjacent coil section 2*b* by the conductive coupling and the capacitive coupling. The output wave form caused by this crosstalk is measured at the point B of the adjacent signal transmitting line. For comparison, the dotted line 39 shows the crosstalk output wave form of the conventional laminated inductor measured at the point B. The amplitude of the dashed line 38 is smaller than that of the dotted line 39. This indicates that the crosstalk of the laminated inductor 1 is smaller than that of the conventional laminated inductor.

## SECOND EMBODIMENT: FIG. 16

FIG. 16 shows a laminated inductor 41 which is the second embodiment of the present invention. The laminated inductor 41 comprises a plurality of coil sections 42*a* and 42*b* which are composed by laminating insulating layers and coil conductors alternately. The coil sections 42*a* and 42*b* are formed by connecting the coil conductors electrically by through holes which are provided on the insulating layers. The coil sections 42*a* and 42*b* are staggered in the horizontal direction of the inductor 41. Thus, the space between two adjacent coil sections is larger than that of a conventional laminated inductor.

Both ends of the coil sections 42*a* and 42*b* are connected with external electrodes 46 and 47 which are provided on sides of the inductor 41 through the leading sections 44*a*, 44*b*, 45*a* and 45*b* respectively.

In the above laminated inductor 41, since the space between two adjacent coil sections 42*a* and 42*b* is larger than that of a conventional one, the conductive coupling and the capacitive coupling between the coil sections 42*a* and 42*b* become smaller. Accordingly, in the laminated inductor, crosstalks between the coil sections can be decreased.

## THIRD EMBODIMENT: FIG. 17

FIG. 17 shows a laminated inductor 51 which is the third embodiment of the present invention. The laminated inductor 51 comprises a plurality of coil sections 52*a* and 52*b* which are composed by laminating insulating layers and coil conductors alternately. The coil sections 52*a* and 52*b* are composed by connecting the coil conductors electrically by through holes which are provided on the insulating layers. The coil section 52*a* and 52*b* are provided staggered in the vertical direction, that is, the coil sections 52*a* and 52*b* are provided on different levels. Thus, compared with a conventional laminated inductor, the space between two adjacent coil sections 52*a* and 52*b* become larger. Both ends of the coil sections 52*a* and 52*b* are connected with external electrodes 56 and 57 which are provided at sides of the inductor 51 through leading sections 54*a*, 54*b*, 55*a* and 55*b*.

The above laminated inductor 51 has the same function and effect as the one of the first embodiment.

## OTHER EMBODIMENTS

Even in a case of staggering coil sections in the vertical direction, as shown in FIG. **18**, part of a coil section **62***a* and a part of a coil section **62***b* adjacent to the coil section **62***a* can be provided on the same insulating sheet. In this case, compared with the inductor **1** which is the first embodiment of the present invention, wherein the conductors of a coil section **2***a* and the conductors of a coil section **2***b* are provided on the lower half insulating sheets **11***g* through **11***j* and on the upper half insulating sheets **11***b* through **11***e* respectively, the effect to decrease the cross-talk becomes weak. However, this type is more downsizing. Also, the conductors of the coil section is not limited to be formed into a spiral and can be formed into straight line.

Further, in the above embodiments, insulating sheets having coil conductors thereon, the producing method is not limited to the above. For example, the following producing method can also be adopted. Paste of an insulating material is applied onto a base by screen printing. After the insulating material is dried and forms an insulating layer, paste of a conductive material is applied onto the surface of the insulating layer to form a coil of a predetermined pattern. After the conductive material is dried and forms coil conductor, the insulating material paste is applied onto the coil conductor. The insulating material is dried and forms another insulating layer. An inductor which has a laminate structure can be obtained by applying these materials alternately.

Although the present invention has been described in connection with the preferred embodiments above, it is to be noted that various changes and modifications are apparent to a person skilled in the art. Such changes and modifications are to be understood as being within the scope of the present invention.

What is claimed is:

**1**. An array type of a laminated inductor noise filter for insertion in a signal transmitting line comprising:

at least three inductors, each of said inductors including,

a coil section, which is formed of alternating laminating insulating layers and coil conductors, said coil section having a spiral coil which is formed by connecting coil conductors electrically through the insulating layers,

a pair of leading sections which have different lengths and extend from said coil section to opposite sides of the laminated inductor, and

a pair of in-line type of external electrodes which are disposed on opposite sides of the laminated inductor, said in-line type of external electrodes being connected to said coil section through said leading sections;

the coil sections of the inductors being staggered in both a vertical direction and a first horizontal direction of the inductor to reduce magnetic coupling between the coil sections, and the coil section for one of said inductors and one of said pair of leading sections for an adjacent inductor to the one inductor being staggered in the vertical direction, and axes of the spiral coils of the coil sections being displaced from one another along a second horizontal direction of the inductor and being staggered in said first horizontal direction of the laminated inductor.

**2**. An array type of a laminated inductor according to claim **1**, wherein the coil sections are formed by laminating insulating sheets having the coil conductors therein.

**3**. An array type of a laminated inductor according to claim **1**, wherein said coil sections are arranged at equal intervals.

* * * * *

June 9, 1936. W. VAN B. ROBERTS 2,043,774

COUPLING ARRANGEMENT FOR AMPLIFIERS AND REPEATERS

Original Filed Sept. 2, 1926

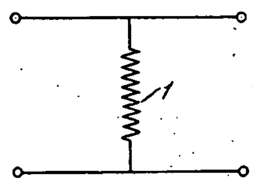



Fig. 1

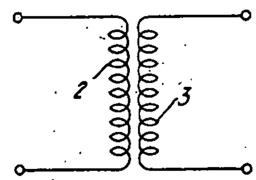



Fig. 2

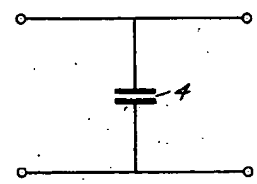



Fig. 3

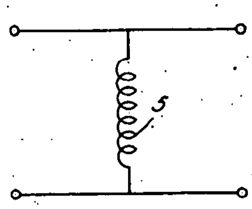



Fig. 4

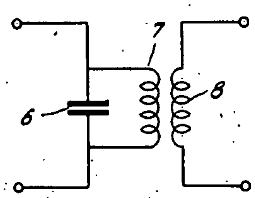



Fig. 5

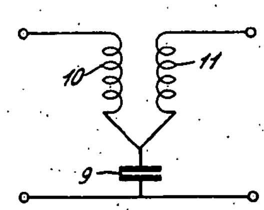



Fig. 6

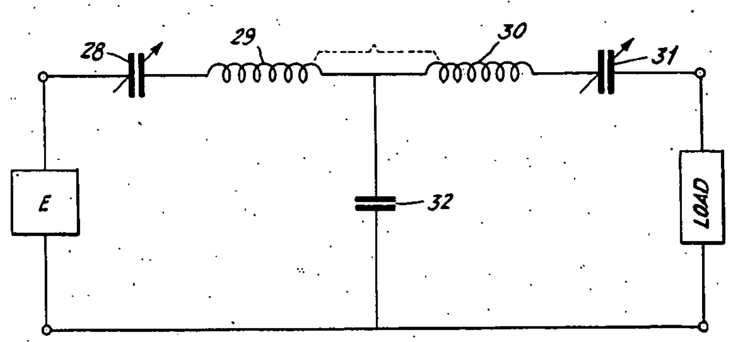



Fig. 7

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Patented Jun 9, 1936 2,043,774

# UNITED STATES PATENT OFFICE

2,043,774

## COUPLING ARRANGEMENT FOR AMPLIFIERS AND REPEATERS

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Original application September 2, 1926, Serial No. 133,283. Divided and this application September 9, 1932, Serial No. 632,318

9 Claims. (Cl. 178—44)

The invention which is a division of application Serial No. 133,283, filed September 2nd, 1926, relates to couplings through which a large range of frequencies are ordinarily used. It relates more particularly to radio frequency amplifiers, but is not limited to the exact range of frequencies which are ordinarily understood to be included in the radio frequency range. It might be also applicable to audio frequencies or even lower.

It has been known in connection with ordinary coupling arrangements heretofore used which intercouple different elements of energy changing arrangements such as amplifiers, detectors, etc., used with oscillatory currents, that the particular couplings were always susceptible and responsive to one particular frequency which predominated over all of the others. This was due to the inherent characteristics of the coupling elements, particularly the relation between the capacity and the inductance of the circuits.

In a great many cases throughout the radio and electrical art there is a necessity for coupling between two or more circuits. These circuits are said to be coupled when an alterating current flowing in one produces an electromotive force in the other. The number of volts of electromotive force produced in either circuit per ampere in the other circuit is called the mutual impedance between the two circuits. This mutual impedance may be obtained in several different ways.

If the two circuits are coupled by means of a mutual inductance, sometimes called a transformer, the mutual impedance increases directly with the frequency. In many cases it is desirable that the mutual impedance between the circuits be independent of frequency or that it vary with frequency less rapidly than with the ordinary case of the mutual inductances.

The objects of this invention are to obtain means for controlling the variation of mutual impedance. It may be controlled in such a way that it will be made to vary in any desired manner with the frequency. The manner for doing this and other objects, some of which will be found to be obvious from, and are explained more precisely in connection with the annexed drawing and the specification.

In this drawing,

Fig. 1 shows a resistance coupling;

Fig. 2 shows the mutual inductance coupling;

Fig. 3 shows a capacitance coupling;

Fig. 4 shows a self-inductance coupling;

Fig. 5 shows modification of Fig. 3 and

Figs. 6 and 7 show modifications and adaptations of the improved coupling means.

In connection with Fig. 1, element 1 shows a resistance where the mutual impedance is simply equal to the resistance and hence is practically independent of frequency. In other words, the coupling values are constant regardless of the change in frequency.

2 and 3 of Fig. 2 show intercoupled inductance coils. The terminals at the left may be connected to one circuit and the terminals at the right are connected to another circuit in a similar way as Fig. 1 may be connected. In this type of coupling, as explained before, the mutual impedance between these two circuits varies directly with the frequency so that with an increase of frequency an increase of coupling exists. Also difficulties arise from the fact that there are other elements entering into the system, such as distributed capacity which causes the curve defining a mutual inductance throughout a given range of frequencies to deviate from a straight line.

4 in Fig. 3 is a condenser used for coupling between two circuits. This type of coupling works just the opposite from the type shown in Fig. 2; that is, the mutual impedance, due to a condenser common to both circuits, increases directly as the wavelength or varies as the reciprocal of the frequency.

5 in Fig. 4 shows a single inductance coil and is substantially the same type of coupling as is shown in Fig. 2, inasmuch as the magnitude of the mutual impedance varies directly as the frequency. This is what is commonly known as the auto-transformer arrangement.

6, 7 and 8 of Fig. 5 show respectively a capacity shunted by an inductance coil which is coupled to another inductance coil. This type of coupling can be made approximately equivalent to the type shown in Fig. 3 over moderate ranges of frequency, as the transformer is so designed with respect to the capacity as to make the mutual impedance vary inversely with the frequency over the desired range of frequencies.

Now, in many cases it is desirable that the mutual impedances between two circuits be independent of frequency, or that it vary with frequency less rapidly than in Figs. 2, 3, 4 and 5. It is usually impractical to use resistance coupling for this purpose as it introduces energy losses which are undesirable. My invention consists in the method of utilizing both inductive and capacitive coupling at the same time so that as the mutual impedance of one element decreases that of the other element increases and vice versa. By proper choice of the relative magnitudes of the two coupling means, the total

mutual impedance may be made to stay as nearly constant as there is any need for over a range of frequencies, such as is used in what is commonly known as the "broadcast range" or that range of frequencies commonly used between 200 and 600 meters.

If desired, the relative values of the two coupling means may be designed so that the total mutual impedance increases somewhat with the frequency, but not so rapidly as the mutual impedance due to the simple inductive coupling. Fig. 6 shows in the simplest form, this type of compound coupling in which **10** and **11** are mutual inductances connected through a common capacity **9**. The intercoupled circuits may be connected to the right and left hand terminals respectively, as before. It is essential that the windings **10** and **11** be in opposite directions so that the voltages produced by the inductive and capacitive couplings add to each other rather than to subtract from each other, which would be the case if an attempt was made to combine the arrangements shown in Fig. 3 and Fig. 4, to make a coupling element consisting of a coil in series with a condenser. However, this last mentioned coupling combination is useful in wave traps and filters where it is desired that the mutual impedance vanish completely for some particular frequency.

Still another use for compound coupling is in connection with continuously tunable radio frequency filters. The width of the band of frequencies passed by a simple filter depends upon the mutual reactance between sections so that as it is desired to select a band of frequencies some ten kilocycles wide no matter what part of the spectrum of broadcast frequencies we are selecting from, it is desired to have a mutual impedance element whose value does not vary appreciably over the broadcast range. Fig. 7 shows a typical filter section using this type of coupling. This is an adaptation of the coupling arrangement shown in Fig. 6, where the transformer coils of the filter are coalesced with the rest of the inductances. Here **28** and **31** are adjustable condensers, one in each side of the two circuits. **29** and **30** are inductances associated as in Fig. 6 and **32** is the mutual capacity.

A source of radio frequency voltage E is conventionally shown connected across the input terminals of the filter, the source being a signal energy collecting means, or a preceding amplifier of collected signal energy, as is well known to those skilled in the prior art. Across the output terminals of the filter is connected a load conventionally represented equal to the value of terminating resistances. This load has a resistance value correct for ensuring the proper uniform band pass selecting characteristic of the filter. The selected currents flowing through the load may be utilized to operate translating devices in any of the usual ways well known to those skilled in the art of radio reception. The term filter, as used heretofore, is understood to imply to those skilled in the art, the mathematical relations between the filter element and, additionally, the inclusion and nature of the voltage source, as well as the output load or terminating resistance.

It will be understood that if the resistances of the coils vary with frequency, as is usually the case, the compound coupling will not be designed for constant mutual impedance but will be so proportioned that the total mutual impedance increases with frequency to the extent desirable to keep pace with the increase of resistance. The values of resistances in two coupled circuits always determine the optimum values of the mutual impedance between the circuits. Care should therefore be taken to prevent unnecessary effective resistances at any particular frequency.

While I have indicated and described several systems for carrying my invention into effect, it will be apparent to one skilled in the art that my invention is by no means limited to the particular organizations shown and described, but that many modifications may be made without departing from the scope of my invention as set forth in the appended claims.

What I claim is:

1. The method of radio reception, which comprises effecting selection of modulated radio frequency energy by cascaded tuned circuits, and utilizing combined condensive and inductive coupling reactions in aiding phase between the circuits to effect transfer of radio frequency energy modulated at audio frequencies with high uniformity and selectivity of the modulated radio frequency energy through a frequency range corresponding substantially to the range of audio frequencies.

2. The method of radio reception, which comprises effecting selection of modulated radio frequency energy by adjusting cascaded tunable circuits to individual resonance at the carrier frequency of said energy, and utilizing combined capacitative and magnetic coupling reactions in aiding phase between the circuits to effect substantially uniform transfer of the selected modulated radio frequency energy through a range of frequencies substantialy co-extensive with the limits of modulation of said energy.

3. In an electrical wave transmission system, an exciting circuit, a load circuit, an adjustable means in each of said circuits for selecting any of a plurality of waves in the broadcast frequency range, and means having capacity and inductive reactance for coupling said circuits, said means comprising mutual inductance between said circuits and a condenser common to both said circuits, said mutual inductance and condenser providing inductive and capacity couplings which are additive in effect and cooperate to transmit all waves in said frequency range with a width of substantially ten kilocycles.

4. A band selective transmission network comprising a pair of syntonous tuned circuits, means for varying the resonance of said circuits, coupling means therefor adapted to produce an increase in the width of the selected band as the frequency of tuning is increased, and additional coupling means adapted to produce a band width variation complementary to that due to said first mentioned coupling means, whereby the band width is substantially constant for a wide range of tuning frequencies.

5. A band selective transmission network comprising a pair of syntonous tuned circuits, means for varying the resonance of said circuits, coupling means therefor adapted to produce an increase in the width of the selected band as the frequency of tuning is increased, and additional coupling means adapted to produce a band width variation complementary to that due to said first mentioned coupling means, whereby the band width is substantially constant for a wide range of tuning frequencies, and one of the said coupling means comprises an impedance connected in shunt between the tuned circuits and the other

of said coupling means comprises an impedance connecting the tuned circuits serially.

6. A band selective transmission network comprising a pair of syntonous tuned circuits, means for varying the resonance of said circuits, coupling means therefor adapted to produce an increase in the width of the selected band as the frequency of tuning is increased, and additional coupling means adapted to produce a band width variation complementary to that due to said first mentioned coupling means, whereby the band width is substantially constant for a wide range of tuning frequencies, and one of the said coupling means comprises an impedance common to each of the said tuned circuits and the other of said coupling means comprises an impedance connecting said tuned circuits serially.

7. A band selective transmission network comprising a pair of syntonous tuned circuits including variable tuning condensers of equal capacity, coupling means for said circuits comprising an impedance common to both circuits which is capacitive throughout the tuning range of the network and additional inductive coupling means comprising coupled windings phased to aid the capacitive coupling throughout the tuning range, said capacitive coupling and said inductive coupling being proportioned to provide a substantially constant width transmission band throughout the range of frequencies to which the network can be tuned.

8. A band selective transmission network comprising a pair of syntonous tuned circuits including variable tuning condensers, coupling means for said circuits comprising an impedance common to both circuits which is capacitive throughout the tuning range of the network and additional inductive coupling means comprising coupled windings phased to aid the capacitive coupling throughout the tuning range, said capacitive coupling and said inductive coupling being proportioned to provide a substantially constant width transmission band throughout the range of frequencies to which the network can be tuned.

9. A signal selective network, comprising a plurality of resonant non-amplifying circuits, each of said circuits simultaneously tunable to substantially the same desired frequencies, said circuits coupled both inductively and capacitatively, the coupling inductances being fixed, and the capacitative and inductive values adjusted so that the coupling co-efficient decreases as frequency increases without a mechanical adjustment of the coupling instrumentalities, in such a way that selectivity remains substantially uniform over the tuning range.

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# UNITED STATES PATENT OFFICE

2,027,986

## SUPERHETERODYNE RECEIVER

Rupert I. Kinross, London, England, assignor to Electric & Musical Industries, Ltd., Hayes, Middlesex, England, a corporation of Great Britain

Application November 10, 1933, Serial No. 697,393
In Great Britain December 19, 1932

8 Claims. (Cl. 250—20)

The present invention relates to wireless receivers of the supersonic heterodyne type.

In supersonic heterodyne wireless receivers, oscillations due to a wanted signal are heterodyned by oscillations from a local source to produce supersonic beat-frequency oscillations. Usually, the frequency of the oscillations from the local source is made variable, and means such as a tunable input circuit are provided to select the wanted signal oscillations while attenuating oscillations due to unwanted signals; an amplifier fixedly tuned to the beat or intermediate frequency is also usually provided.

Receivers of this type are found to introduce a form of signal interference not normally experienced with other types of receivers. This interference, which is known as "image" frequency interference, may occur for example when the signal-selecting circuit of a receiver is tuned to the frequency of one of two transmissions which are separated from one another by approximately twice the intermediate frequency of the receiver, or by certain fractions of twice the intermediate frequency. In these circumstances, one signal may be heard as a background to the other, or, if the frequency difference between the wanted and unwanted oscillations fed to the intermediate amplifier lies within the audible range, the interference may manifest itself as a whistle at the difference frequency. The interference is particularly noticeable when the interfering signal is that due to a powerful local transmitting station.

The amount of image frequency interference experienced depends in part on the selectivity of the signal selecting circuit. In broadcast receivers, it is customary to employ some form of band pass filters for this purpose, but since considerations of cost usually limit the number of filter sections employed to two or three, sufficient selectivity cannot normally be attained to restrict image frequency interference to an unobjectionable amount.

It is an object of the present invention to provide a supersonic heterodyne wireless receiver in which "image" frequency interference is eliminated or reduced.

According to the present invention, a supersonic heterodyne wireless receiver comprises an input circuit, a second circuit and a coupling between these circuits such that oscillations are transferred from said input circuit to said second circuit, one or both of said circuits being tunable to the frequency of a wanted oscillation, there being also provided between said circuits a capacitive coupling and an inductive coupling for the purpose of feeding into said second circuit oscillations in antiphase to the oscillations transferred thereto by the first-mentioned coupling. Preferably, the magnitudes of both said capacitive and inductive couplings are made variable over suitable ranges.

The novel features which I believe to be characteristic of my invention are set forth in particularity in the appended claims. The invention itself, however, both as to its organization and method of operation will best be understood by reference to the following description, taken in connection with the drawing in which I have indicated diagrammatically a circuit organization whereby my invention may be carried into effect.

The invention will be described by way of example with reference to the accompanying drawing in which

Fig. 1 is a circuit diagram illustrating a part of a superheterodyne receiver circuit constructed according to the invention, and

Figs. 2, 3 and 4 are curve sheets used in illustrating the principles involved in the invention.

Referring to Fig. 1, a supersonic heterodyne wireless receiver comprises a screen grid valve 1 of the indirectly heated type adapted to function both as the local oscillator and the first detector, and has an input band pass filter constituted by two inductively coupled tunable circuits. The first tunable circuit comprises a suitable coil 2 connected in parallel with a variable condenser 3, the aerial being connected to a tapping point on a high resistance potentiometer 4. One end of the potentiometer 4 is connected to earth, while the other end is connected to a tapping point in the coil 2 through a small fixed series condenser 5.

The second tuned circuit comprises a coil 6 inductively coupled to the coil 2 of the first tuned circuit, and connected in parallel with a variable condenser 7 which is preferably ganged, as indicated by a broken line, with the variable condenser 3 of the first tuned circuit and with the tuning condenser 8 of the circuit 9 which determines the frequency of the local oscillations. The low potential ends of the two tunable circuits constituting the input band pass filter are earthed. The cathode of the detector-oscillator valve 1 is connected to earth through a coil 10 inductively coupled to the coil 11 of the tunable circuit 9, and the high potential end of the tunable circuit 6, 7 is connected to the control grid 12

of the detector-oscillator valve 1 through a grid leak 13 and grid condenser 14 in parallel.

The anode of the valve 1 is connected to the positive terminal 17 of a source of high tension current through a parallel tuned circuit 18 tuned to the intermediate frequency. The circuit 18 is inductively coupled to a similar circuit 19 and the two circuits form a band pass filter. The terminals 20 and 21 are connected to the input circuit of a suitable intermediate frequency amplifying valve.

Connected between the high potential ends of the tunable circuits 2, 3 and 6, 7 is a small condenser 15, which is preferably variable over narrow limits, and may conveniently be formed by two pieces of stout wire insulated at their ends by rubber sleeving or the like, the insulated ends being secured together in such a manner that the wires are movable in the sleeving to vary the capacity between them. Alternatively, the condenser 15 may be constituted by two screws so arranged that the distance between their heads, which face one another, is adjustable. The effect of this small capacity is to produce in the tunable circuit 6, 7 impulses of the unwanted frequency in opposite phase to those transferred inductively from the tunable circuit 2, 3 to the tunable circuit 6, 7, and the value of the capacity can be made such that the two sets of impulses substantially cancel one another. So long as the unwanted image frequency lies outside the band to which the filter is tuned, substantially complete cancellation can be obtained.

Since the impedance of the condenser increases with increase in wave-length, the anti-phase feed will decrease with increase in wave-length. It is found, however, that the band width of the type of band-pass filter described above narrows with increase in wave-length. Less anti-phase feed will therefore be required for perfect neutralization as the wave-length increases. This condition is satisfied only approximately by the use of the condenser, since the capacity feed from the latter decreases more rapidly with increase in wave-length than is required by the condition that the band width is also narrowing. Fullest advantage can only be taken of the capacity feed by arranging its value to be such as to give maximum neutralization towards the lower end of the wave band to be covered by the kind of band-pass filter described above.

Fig. 2 illustrates this point graphically, the amount of interference obtained using capacity feed being plotted vertically, while wave length is plotted horizontally. The capacity of the condenser 15 is preferably made such that when the receiver is arranged for reception within the medium wave band (200–600 metres) maximum suppression of interference is produced at a wave length of about 320 metres. As will be seen, the amount of suppression obtained decreases towards the upper part of the wave band and there is therefore connected between the aerial series condenser 5 and the coil 2 of the tunable circuit 2, 3, a coil 16 of small inductance which is so coupled to the coil 6 of the tunable circuit 6, 7 as to produce in that circuit impulses of opposite phase to those transferred inductively thereto from the tunable circuit 2, 3.

The coil 16 may comprise two or three turns of wire upon a wooden former of about 1½ inches in diameter. The coil 16 may be mounted at the side of the coil 6 by means of a screw passing through a hole drilled eccentrically in the former. Both coils are mounted side by side upon the same base with their longitudinal axes parallel. The magnitude of the inductive coupling may be adjusted by rotating the former of the coil 16, the screw being tightened when the correct value is attained.

The sense of the coupling between the coil 16 and the coil 6 of the second tunable circuit is made such that the two sets of impulses induced into the second tunable circuit (one through the coupling 2, 6 and the other through the coupling 16, 6) tend to cancel out, the effect being arranged to be most marked at the higher wave-lengths.

Fig. 3 shows the amount of suppression due to the inductive coupling alone. The magnitude of the coupling is preferably made such that for medium wave-band reception maximum suppression is obtained at about 500 metres. By a suitable choice of values of the reverse-phase feed capacity and mutual inductance, it is possible to eliminate or reduce substantially interference due to image frequency oscillations over the whole of the wave band to which the receiver is tunable.

Fig. 4 is a curve showing the combined effect of the capacitive and inductive feed. As before, interference is plotted vertically, and wave length horizontally, and it will be seen that substantially complete suppression of interference is obtained over two ranges of frequencies within the desired frequency band. It will be apparent that impulses at the wanted frequency as well as at the unwanted frequency are induced in the tunable circuit 6, 7 by the coupling due to the elements 15 and 16. Over the band of frequencies to which the input band pass filter responds, the amount of anti-phase feed is substantially uniform, and it is permissible to represent its effect as being to lower the response curve of the filter a substantially uniform amount relatively to its original datum line. Thus, by effectively removing or reducing the "skirts" of the response curve of the input filter, the invention enables interference due to signals within the frequency range of the "skirts" to be eliminated or reduced.

When the receiver is tunable to more than one wave band, the values of the feed capacity and mutual inductance may be varied by connecting additional condensers and inductances in parallel with those employed for the lowest wave band. The switches for this purpose may be ganged with the usual wave-range changing switch of the receiver.

In supersonic heterodyne receivers such as that described above, in which no high frequency amplifier is provided, and in which the tunable input circuit is connected directly to the first detector, there may be a certain amount of radiation by the aerial of oscillations due to the local source. It will readily be seen that the amount of radiation will also be substantially reduced by the use of the reverse-phase feed condenser 15 and coil 16 which, in this case, operate to eliminate or to reduce the amplitude of oscillations in the first tuned circuit due to the local source.

While I have indicated and described a system for carrying my invention into effect, it will be apparent to one skilled in the art that my invention is by no means limited to the particular organization shown and described, but that many modifications may be made with-

out departing from the scope of my invention as set forth in the appended claims.

What I claim is:—

1. A supersonic heterodyne wireless receiver comprising an input circuit, a second circuit and a coupling between these circuits such that oscillations are transferred from said input circuit to said second circuit, at least one of said circuits being tunable to the frequency of a wanted oscillation, auxiliary coupling means between said circuits comprising an inductive coupling and a capacitive coupling said auxiliary coupling means acting to transfer energy from the input circuit to the second circuit in phase opposition with respect to the energy transferred by the first named coupling and of such intensity to substantially buck out unwanted oscillations transferred from the input circuit to the second circuit through the first named coupling.

2. A wireless receiver according to claim 1, wherein the magnitudes of said capacitive and said inductive couplings are made such that substantially complete suppression of oscillations of the unwanted frequency is obtained over two bands of frequencies within the range of frequencies to be received.

3. A supersonic heterodyne wireless receiver comprising an input circuit, a second circuit and a coupling between these circuits such that oscillations are transferred from said input circuit to said second circuit, at least one of said circuits being tunable over a predetermined band of frequencies for signal selection, auxiliary coupling means between said circuits arranged so as to feed into the second circuit oscillations in phase opposition to the oscillations transferred thereto through the first named coupling means, said auxiliary coupling means having inherent frequency discriminating characteristics due to which the intensity of the energy transferred therethrough is different for different portions of said frequency range and energy transference means between the primary circuit and the second circuit for compensating for the frequency discriminating effects of the auxiliary circuit.

4. A wireless receiver, according to claim 3, wherein said second coupling is of a substantially wholly inductive nature.

5. A wireless receiver, according to claim 3, wherein said compensating means comprises a further coupling of a substantially wholly capacitive nature.

6. In a superheterodyne receiver, an input circuit, a second circuit, coupling means between the circuits such that oscillations are transferred from the input circuit to the second circuit, at least one of said circuits being tunable over a predetermined band of frequencies for signal selection, auxiliary coupling means between said two circuits comprising an inductive coupling and a capacitive coupling, said auxiliary coupling means acting to transfer energy from the input circuit to the second circuit in phase opposition to the energy transferred through the first named coupling means, the energy transferred through the capacitive coupling portion of the auxiliary coupling means being of such intensity as to substantially completely suppress unwanted oscillations transferred from the input circuit to the second circuit through the first named coupling means over a range of frequencies which is near one end of said frequency range, the energy transferred through the inductive portion of the auxiliary coupling means being of such intensity as to substantially completely suppress unwanted oscillations transferred from the input circuit to the second circuit through the first named coupling means over a range of frequencies which is near the other end of said frequency range.

7. In a superheterodyne receiver, an input circuit, a second circuit, means for coupling said circuits so that oscillations are transferred from the input circuit to the second circuit, at least one of said circuits being tunable over a predetermined band of frequencies to provide signal selection, auxiliary coupling means between said circuits arranged so as to feed into the second circuit oscillations in phase opposition to the oscillations transferred thereto through the first named coupling means, said auxiliary coupling means having inherent frequency selective characteristics due to which the intensity of the energy transferred therethrough varies for different portions of the said frequency range and means connecting the input circuit and the second circuit for compensating for the frequency discriminating effects of the said auxiliary circuit.

8. In a superheterodyne receiver a primary circuit, a secondary circuit, means for coupling said two circuits so that oscillations are transferred from the primary circuit to the secondary circuit at least one of said circuits being tunable over a predetermined band of frequencies to provide signal selection, auxiliary coupling means between said two circuits comprising an inductive coupling and a capacitive coupling each of said couplings being separately adjustable so as to separately control the amount of energy transferred therethrough, said auxiliary coupling means being arranged so as to transfer energy from the primary circuit to the secondary circuit in phase opposition with respect to the energy transferred through the first named coupling means, the energy transferred through the capacitive coupling portion of the auxiliary coupling means being of such intensity as to substantially suppress unwanted oscillations transferred from the primary circuit to the secondary circuit through the first named coupling means over a range of frequencies which is near one end of said frequency range, the energy transferred through the inductive portion of the auxiliary coupling means being of such intensity as to substantially completely suppress unwanted oscillations transferred from the primary circuit to the secondary circuit through the first named coupling means over a range of frequencies which is near the other end of the frequency range.

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